PB86-230851

Evaluation of Performance Characteristics of Emissions from Hazardous Waste Incinerators with a Mobile Laboratory

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Aug 86

U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-230851

EPA/600/D-86/168
August 1986

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by

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TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA/600/D-86/168	2.	3. RECIPIENT'S ACCESSION NO. PB86 230851/AS
4. TITLE AND SUBTITLE Evaluation of Performance Characteristics of Emissions from Hazardous Waste Incinerators with a Mobile Laboratory		5. REPORT DATE August 1986
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Sharon L. Nolen and Merrill D. Jackson		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS See Block 12.		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-3988
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Published paper; 6-12/85
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Sharon L. Nolen, Mail Drop 62, 919/541-7607. For presentation at ASME Winter Meeting, Anaheim, CA, 12/7-12/86.

16. ABSTRACT The paper discusses the evaluation of performance characteristics of emissions from hazardous waste incinerators with a mobile laboratory. The EPA has increasingly viewed incineration as an effective way to destroy hazardous waste. Incinerators are permitted, under RCRA, to burn hazardous waste. The CO level observed during a trial burn, when destruction and removal efficiency (DRE) compliance is achieved, is used as one basis for monitoring the routine operation of an incinerator. DRE is widely accepted as an indicator of incinerator performance. Because of the interest in monitoring incinerator performance on a real-time basis, the EPA designed and built a mobile laboratory for on-site monitoring of hazardous waste incinerator emissions and operating parameters. The result, the Hazardous Air Pollutants Mobile Laboratory (HAPML), is equipped with monitors for on-line analysis of inorganic and organic stack gas emissions. The HAPML has demonstrated its usefulness in a field test of an industrial boiler co-firing hazardous waste. The complete boiler test was conducted by EPA's Hazardous Waste Engineering Research Laboratory in Cincinnati to obtain more detailed environmental performance information that is to be reported separately. The field test showed that combustion efficiency (CE) may have potential for use as an incinerator performance indicator.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Mobile Equipment	Pollution Control	13B	15E
Hazardous Materials		Stationary Sources	11G	
Wastes	Efficiency	Destruction and Removal Efficiency (DRE)	14G	
Toxicity	Evaluation		06T	
Incinerators	Carbon Monoxide			07B
Laboratories	Combustion Efficiency		14B	21B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	17
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

EVALUATION OF PERFORMANCE CHARACTERISTICS OF EMISSIONS FROM HAZARDOUS WASTE INCINERATORS WITH A MOBILE LABORATORY*

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Abstract

The Environmental Protection Agency (EPA) has increasingly viewed incineration as an effective means of destroying hazardous waste. Incinerators are permitted, under the Resource Conservation and Recovery Act (RCRA), to burn hazardous waste. The carbon monoxide (CO) level observed during a trial burn, when destruction and removal efficiency (DRE) compliance is achieved, is used as one basis for monitoring the routine operation of an incinerator. DRE is widely accepted as an indicator of the performance of an incinerator.

Because of the interest in monitoring the performance of incinerators on a real-time basis, the EPA designed and built a mobile laboratory for on-site monitoring of a hazardous waste incinerator's emissions and operating parameters. The result, the Hazardous Air Pollutants Mobile Laboratory (HAPML), is equipped with monitors for on-line analysis of inorganic and organic stack gas emissions. The HAPML has demonstrated its usefulness in a field test of an industrial boiler co-firing hazardous waste. The complete boiler test was conducted by EPA's Hazardous Waste Engineering Research Laboratory's (HWERL) Thermal Destruction Branch (TDB) of Cincinnati, under the direction of Ivars J. Licis for EPA's Office of Solid Waste (OSW), as requested by Marc Turgeon, to obtain more detailed environmental performance information that will be reported separately.

Results from the field test indicate that combustion efficiency (CE), which is much less expensive to determine than DRE and can be obtained continuously, may have potential for use as an incinerator performance indicator. In all tests DRE exceeded its compliance level of 99.99%, and CE exceeded its minimum level required for at-sea incineration, 99.95% +_ 0.05%. Furthermore, the relationship between CE and CO appears to be similar to that between DRE and CO. Additional tests with the boiler operating in an upset condition are required to determine if a correlation exists between CE and DRE.

Mention of trade names is for identification only and does not constitute endorsement by the U. S. Environmental Protection Agency.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for publication.

INTRODUCTION

The Environmental Protection Agency's (EPA) view concerning the disposal of hazardous waste has changed radically during its history. The Agency has progressed from viewing land disposal as virtually the only means of discarding waste to the restrictions of land disposal found in the Hazardous and Solid Waste Amendments of 1984 (HSWA) (1). As a result of this change in perspective, hazardous waste incineration (HWI) has increasingly been perceived as an effective means of destroying hazardous waste.

The land-based incineration of hazardous waste is regulated by the Resource Conservation and Recovery Act of 1976 (RCRA I) and its 1984 reauthorization (RCRA II). Incinerators are permitted under RCRA by completing a trial burn using the types and levels of wastes or an acceptable substitute to be burned in the unit and meeting certain requirements during the trial. The destruction and removal efficiency (DRE) of the principal organic hazardous constituents

(POHCs) must be at least 99.99%. Hydrochloric acid (HCl) removal must be at least 99% or less than 4 lb/hr (0.5 g/s), and the maximum particulate level must not exceed 0.08 gr/dscf (0.183 g/dsm^3) at 12% carbon dioxide (CO_2). The carbon monoxide (CO) level observed during the trial burn, while the RCRA requirements were achieved, is used as one basis for determining compliance during future operation of the incinerator (2).

DRE is widely accepted as an indicator of the performance of an incinerator. However, obtaining the information to calculate DREs is time consuming, costly, and, at the present time, not possible on a continuous basis. Therefore, CO has been used as an indicator for DRE to continuously monitor incinerator performance on a real-time basis. However, the CO level has been found to represent general trends in DRE without reflecting minor changes (3). Therefore, other parameters are being explored to replace CO as a better indicator of incinerator performance.

Combustion efficiency (CE) is one of the parameters of interest. CE is governed by international agreement for at-sea incineration; however, no criteria have been set for land-based incinerators. The CE is calculated from the CO_2 and CO data generated by two common continuous emission monitors (CEMs):

$$CE = \frac{CO_2 - CO}{CO_2} \times 100$$

where CO_2 and CO refer to the concentration of CO_2 and CO present, respectively. Under the international agreement, CE may not be less than 99.95% $\pm$ 0.05%.

Because of the interest in determining the performance of an incinerator on a real-time basis, the EPA initiated a project to build a mobile laboratory for continuous monitoring of emissions and operating parameters of hazardous waste incinerators. The objective of this project was to provide an integrated sampling and analytical package for evaluation and development of continuous

monitors for hazardous waste incinerators. The result of the project is the Hazardous Air Pollutants Mobile Laboratory (HAPML), designed to be easily transported for use by researchers at a variety of incinerators.

This paper will discuss the development of the HAPML, data obtained while monitoring an industrial boiler burning hazardous waste, and the possibility of using existing continuous monitoring techniques to indicate the performance of an incinerator on a real-time basis.

DEVELOPMENT OF THE HAZARDOUS AIR POLLUTION MOBILE LABORATORY

The HAPML was constructed to serve as an integrated sampling and analytical package for use in hazardous waste incineration research. The HAPML utilizes extractive sampling technology, and all components are housed in a standard 8 m long, self-propelled mobile van.

The laboratory contains continuous monitors for real-time analysis of CO, CO_2, NO_x, O_2, and SO_2. An HCl monitor was acquired after the field test discussed in this paper. Organic analytical instrumentation includes a gas chromatograph (GC) equipped with a flame ionization detector (FID) and a mass spectrometer (MS). All measurement sensors are listed in Table 1.

TABLE 1

MEASUREMENT SENSOR SUMMARY

Parameter	Instrument/Model	Measurement Principle
O_2	MSA Model 802	Paramagnetic
CO	TECO Model 48	Gas filter correlation
CO_2	MSA Model 303	NDIR
SO_2[a]	TECO Model 40	Pulsed fluorescence
NO_x	TECO Model 10	Chemiluminescence
HCl[a,b]	TECO Model 15	Gas filter correlation
Volatile Organics	Hewlett Packard 5890A	Gas chromatograph (FID detector)
	Extranuclear EL 150 (with extended range)	Mass spectrometer
Pressure Differential	Validyne DP 15-22	Pressure transducer
Stack Temperature	Omega Type K	Thermocouple

(a) Requires the TECO 900 sample conditioner
(b) Acquired since field test

The sampling system was designed to deliver a portion of the gaseous effluent in the stack to the HAPML while maintaining sample integrity. Major considerations in on-line analysis include the interferences caused by particulates and moisture and minimizing reactions and interactions in the sample line.

All particulates must be removed from the sample stream because they may result in interferences in the analytical instrumentation. The HAPML uses a particulate removal system located 3 m from the stack sampling port. The particulate removal system is housed in a heated aluminum filter box and consists of a high surface area, low pressure drop, spun glass wool filter.

Water, a natural combustion product, may condense within the analyzers or can result in optical interferences. This problem may be handled in different ways depending on the species of interest. The stack gas emissions flowing to the CO, CO_2, O_2, and NO_x monitors are cooled and dried using a condenser and a Perma-Pure dryer. Since SO_2 and HCl are soluble in water, these gases would be removed along with the water. Therefore, this problem must be resolved with a different procedure. The sample conditioner is used to dilute these gas streams with dry, clean air to minimize the interference effects of water vapor. NO_2 is also soluble in water. However, since NO_x is typically about 95% NO, the loss is considered negligible.

Several considerations are required to ensure that reactions do not occur in the sample line. A heated Teflon line is used to transport the sample from the stack into the mobile laboratory. The temperature of the sample line must be maintained above the boiling point of all compounds of interest. Care must be taken to eliminate any cool spots in the line, such as at fittings. If any chlorine is in the system, Teflon fittings must be used. Stainless steel connections must be removed — they can react with the sample. If Teflon fittings are not available, stainless steel fittings lined with Teflon, which eliminates contact between the stainless steel and the sample, may be used.

The organic analytical system was designed to provide information in a variety of ways. The sampling system may be used to deliver sample gas directly to the GC/MS or the GC/FID for semi-continuous monitoring, to the MS for on-line analysis of selected organic compounds, or to the FID for total hydrocarbon (THC) concentration determination. The HAPML may also be used as an on-site laboratory for analysis. It is equipped with a Volatile Organic Sampling Train (VOST) for collection and concentration of the gas effluent if the compounds of interest

are present below the detection limits of the analytical instrumentation. These samples may be analyzed on the GC/MS while on-site to provide rapid turnaround. A quick analysis may be invaluable in determining the amount of gas to be concentrated to provide the proper range for more extensive analytical procedures. The FID may also be used with the GC for additional information.

Standard gases traceable to the National Bureau of Standards (NBS) are used for quantitative analysis for the CEMs. Standard gases for common organic classes are also used for semiquantitative organic analysis. The HAPML is equipped to handle calibration standards in the form of cylinders or permeation tubes.

All MS and CEM data are acquired by two onboard computers (a Compaq Deskpro 286 and a DEC PDP 11). Strip-chart recorders are available for acquisition of the FID data and as a backup for the CEM data.

FIELD TEST OF THE HAP MOBILE LABORATORY

The HAPML was used in conjunction with the field test of an industrial boiler. The complete boiler test was conducted by EPA's Hazardous Waste Engineering Research Laboratory's (HWERL) Thermal Destruction Branch (TDB) of Cincinnati under the direction of Ivars J. Licis for EPA's Office of Solid Waste (OSW), as requested by Marc Turgeon, to obtain more detailed environmental performance information that will be reported separately. The field test was one of a series of tests to evaluate the feasibility of using industrial boilers to co-fire hazardous waste. Boilers are widely used in industry as an economical means of destroying on-site hazardous waste. These boilers are currently exempt from RCRA.

EPA's first tests found these boilers to produce high DREs (composite weighted DRE of 99.998%) under steady state operating conditions (4). Further tests were then initiated to examine performance of several types of boilers

under normal non-steady state conditions. The field test of the HAPML was held at one of these boilers, Site N.

The purpose of the HAPML's participation in this field test was two-fold. First, it was necessary to evaluate the performance of the mobile laboratory under field conditions. The data obtained with it were to be compared with the data from the on-site instrumentation. Second, the mobile facility was to provide additional support to the HWERL/OSW effort.

FIELD TEST RESULTS

The results of the following variables for seven test conditions are shown in Table 2: O_2, CO_2, CO, CE, and DRE. The corresponding test conditions are listed in Table 3. The first four variables were acquired as 5 minute averages. The data presented in Table 4 demonstrate that the difference between the on-site and HAPML CEMs is within the precision of the instrumentation. The DRE was determined once for each test condition.

Although differences were apparent between tests, an analysis of variance (ANOVA) was performed on the first four variables to confirm that there were statistical differences between the tests to allow for valid conclusions. Statistical differences were found at the $p = 0.0001$ level for all variables. A p - value of 0.05 or less is generally regarded as significant and 0.01 or less as highly significant. It was not unexpected to find a significant difference as the runs included base line data. Separate ANOVAs were also performed on selected pairs of tests with the results discussed below.

Both tests 12 and 13 were burning coal, oil, and trichlorobenzene (TCB) at a low steam load. The only difference between the two tests was the difference in the amount of excess air. The typical level of excess air resulted in an oxygen level of about 7% in the stack. The high level of excess air used

TABLE 2

SUMMARY OF TEST RESULTS

Test No.	N[a]	O_2 Mean(%)/SD[b]		CO_2 Mean(%)/SD		CO Mean(ppm)/SD		CE Mean(%)/SD		DRE
7	18	7.67	0.59	11.13	0.24	22	0.87	99.98	0.0008	99.99991
12	39	7.97	0.95	10.53	0.67	22	3.22	99.98	0.0045	99.9995
13	25	10.49	0.32	8.24	0.59	30	5.63	99.96	0.0079	99.9997
14	12	7.96	0.39	10.62	0.27	24	5.39	99.98	0.0053	100.0000
15	30	5.81	0.50	11.61	0.26	16	2.43	99.99	0.0018	99.9998
16	28	9.70	0.38	9.72	0.36	31	25.87	99.97	0.0262	99.9996
17	43	5.52	0.26	12.24	0.22	23	0.87	99.98	0.0008	[c]

(a) N=Number of data points
(b) SD=Standard deviation
(c) No POHC burned in this test

TABLE 3

SUMMARY OF TEST CONDITIONS

Test No.	Condition
7	High load[a], coal, sludge, and TCB[b]
12	Low load, coal, oil, and TCB
13	Low load, high air, coal, oil, and TCB
14	Low load, coal, oil, and TCE[c]
15	High load, coal, oil, TCB, and metals
16	Low load, high air, coal, sludge, TCB, and metals
17	High load, baseline, coal, and sludge

(a) Load refers to steam
(b) Trichlorobenzene
(c) Trichloroethylene

TABLE 4

COMPARISON OF HAPML AND ON-SITE CEM DATA

	O_2 (%)	CO_2 (%)	CO (ppm)
Instrument Precision	±0.50	±0.15	±10
HAPML Average	7.65	10.70	24
On-Site Average	7.97	10.64	35

produced oxygen levels of 12 to 17%. All four variables in the two tests were found to be statistically different at the $p = 0.0001$ level. The CEMs reflect the differences between the test conditions. Test 13, with high excess air, shows lower levels of CO_2 and CE and higher levels of O_2 and CO. The increase in CO and corresponding decrease in CE are probably due to the extra air's being heated and exhausted. This extra mass of air also shortens the residence time in the combustion chamber. The excess air may serve to quench the reaction, causing the effect mentioned. The increase in the CO level with increasing O_2 is noted for all tests and is shown in Figure 1.

Another pair of tests, 12 and 14, were also compared. The two tests were identical except for the organic material being burned. The POHC burned in Test 14 was trichloroethylene (TCE). There was no statistical difference between the two tests for any of the four variables.

As mentioned earlier, the primary purpose of this field test was to examine the feasibility of using industrial boilers for the destruction of hazardous waste under normal non-steady state conditions. For all tests, the minimum DRE was greater than the compliance level of 99.99% (5). Also for all tests, the CE never went below the minimum of 99.90% required for at-sea incineration. Figure 2 shows that all data points are well within the compliance window as defined by the CE and DRE limits.

The relationship between the accepted DRE indicator, CO, and DRE has been explored (3). It was found that the CO level represents general trends in DRE without reflecting minor changes. The relationship between CO and CE seems to be similar to the relationship between CO and DRE.

The results of the field test demonstrate that the HAPML can be transported to a remote site and produce quality CEM results. Several problems in the

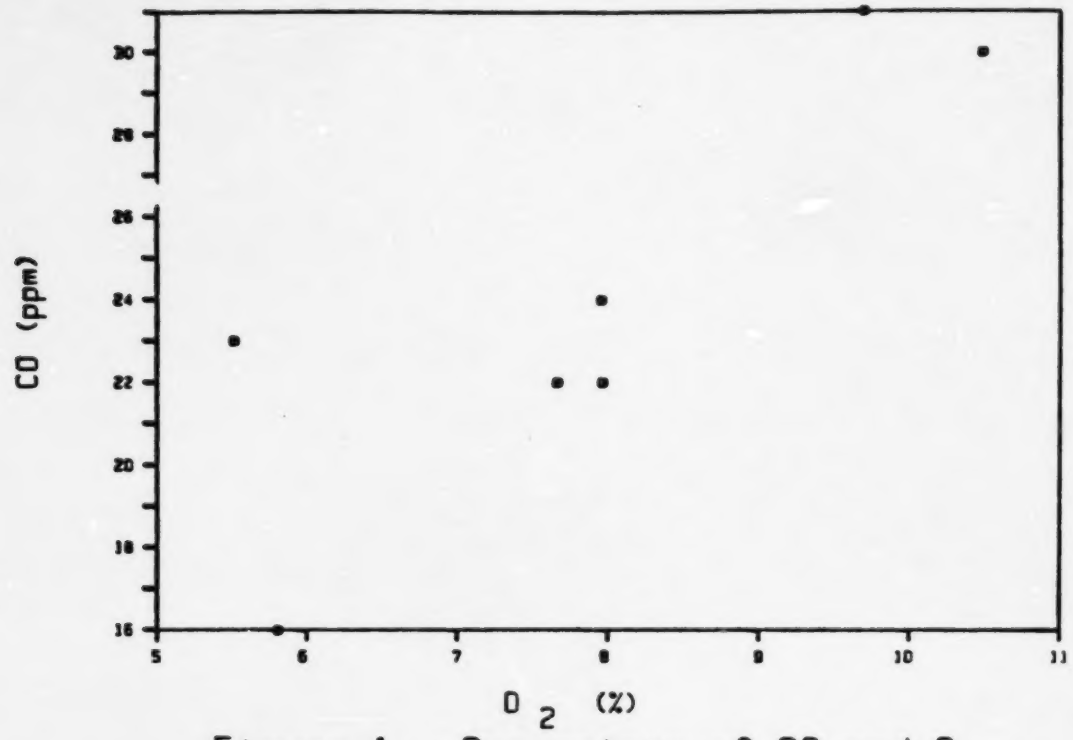

Figure 1. Comparison of CO and O_2.

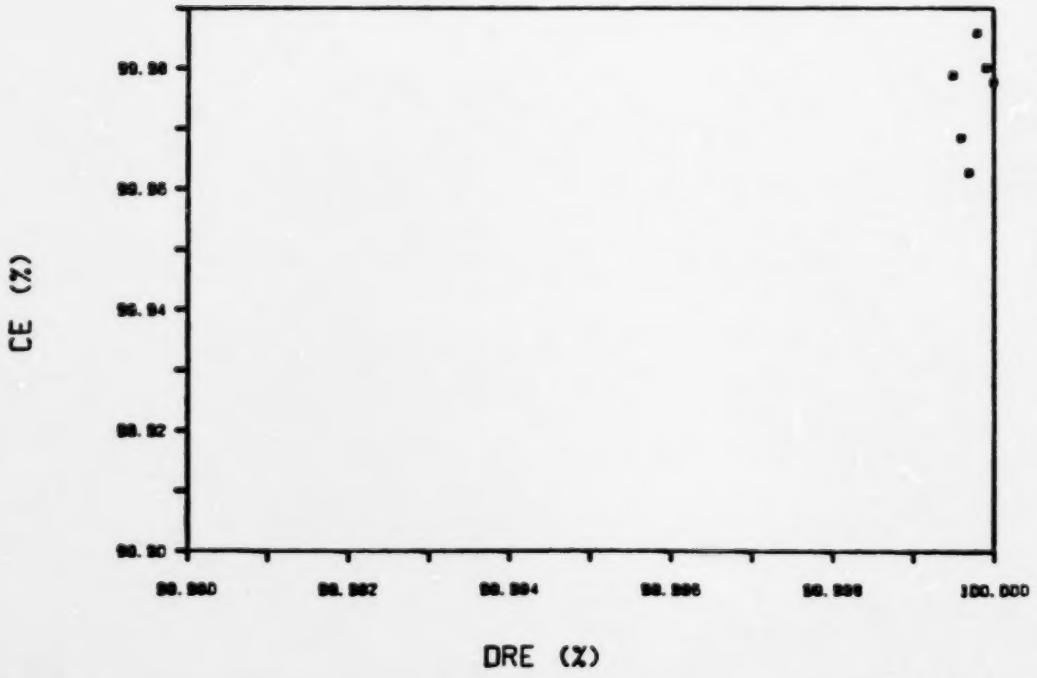

Figure 2. Comparison of CE and DRE.

organic system were identified during the field test, and steps have been taken to correct these problems. The laboratory has since been used successfully to analyze VOST samples from a rotary kiln operated by the EPA at Research Triangle Park.

CONCLUSIONS

It appears that CE may be a promising alternative to CO as an indicator of incinerator performance on a real-time basis. Like CO, CE is easily monitored and is relatively inexpensive to obtain continuously. However, the data generated in this work are limited. As illustrated in Figure 2, all points are at the upper end of the compliance window for both CE and DRE. To more fully determine the relationship between CE and DRE, further tests are required while an incinerator is operating under upset conditions and producing DREs over a greater range including ones less than the compliance minimum.

There is a need for a continuous indicator of incinerator performance. Present work with the mobile laboratory is focused on determining the feasibility of using the MS as a continuous monitor. First, different chemical classes in several concentrations must be tested to ensure delivery of a representative organic sample through the sampling system to the analytical instrumentation. Once this has been successfully demonstrated, the second aspect of the work will investigate the use of the MS as a selective ion monitor for POHCs and products of incomplete combustion (PICs).

ACKNOWLEDGMENT

The authors wish to express their appreciation to Ivars J. Licis of HWERL, D. Bruce Harris of the Air and Energy Engineering Research Laboratory, and Carlo Castaldini and Larry Hamel of the Acurex Corporation for their assistance.

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